## REMARKS

Upon entry of the Amendment, Claims 1-162 are all the claims pending in the application. Claims 159-162 are added. Claims 57-157 are withdrawn from consideration by the Examiner. Claims 1-56 and 158 are rejected.

Reconsideration and review of the claims on the merits are respectfully requested.

### *Formal Matters*

Applicants thank the Examiner for reviewing and considering the references cited in the Information Disclosure Statements filed March 6, 2002 and November 22, 2003.

Applicants also thank the Examiner for approving the formal drawings filed April 21, 2003.

### *Claim Rejections - 35 USC § 103*

**A.** Claims 1, 3, 5, 7, 9, 11, 21, 22, 25, 26, 29-33, 39-43, 49, 50, 53 and 54 (and also apparently Claim 158, as discussed at page 14 of the Office Action) are rejected under 35 U.S.C. §103(a) as assertedly being unpatentable over Marlin (US Patent 6,429,046) in view of Chan et al (US Patent 5,471,092) for the reasons given in the Office Action.

Regarding claim 1, the Examiner recognizes that Marlin fails to teach an intermetallic compound being formed between the solder bump and the UBL. However, the Examiner asserts that Chan et al teaches a solder ball/UBL reflow structure where an intermetallic compound including metals such as tin (Sn) and copper (Cu) is formed after solder reflow of tin based alloy

solder having tin as a main component on a metal/solder reactive layer comprising copper to prevent formation of the intermetallics in the underlying layers, improve adhesion and to reduce the joint stress, the intermetallic compound/Cu-Sn including the main component/metal (Sn) of the alloy solder and the second metal such as Cu, which is different than the main component of the alloy solder.

**B.** Claims 2, 4, 6, 8, 10, 12, 23, 24, 27, 28, 34-38, 44-48, 51, 52, 55 and 56 are rejected under 35 U.S.C. §103(a) as assertedly being unpatentable over Marlin in view of Chan et al and Darveaux et al (US Pat. 6,201,305) for the reasons given in the Office Action.

Regarding claim 2, the Examiner asserts that Darveaux et al makes up for the deficiencies in Marlin and Chan by teaching a solder ball mounting structure having underbump layer such as nickel on a laminated pad where an intermetallic compound such as tin-nickel (SnNi) is formed, the intermetallic compound including the metal/first metal such as nickel and the main component of the alloy of the solder ball such as tin.

Applicants respond as follows.

Applicants amend Claims 1-4 and 158 to clarify that "<u>said second metal also being different from a metal in the under-bump layer</u>", along with other slight editorial changes. Support for the amendment can be found, for example, at page 18, lines 7-10 of the specification as originally filed. Entry of the amendment is respectfully requested.

Applicants submit that the combination of Marlin with Chan, and further in view of Darveaux, does not disclose, teach or suggest each and every requirement of Applicants' claims.

According to the present invention, a semiconductor device is characterized in that an alloy layer, of at least a main component of the alloy solder and a different component which is also different from a metal in the under-bump, or UBM, layer is provided between the solder and the UBM layer. Since part of the UBM layer may melt, the alloy layer may be made of an alloy of a main component of the solder, a component different from the UBM layer, and a component of the UBM layer.

Accordingly, when soldering, the above alloy layer is first formed between the solder and the UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

In Chan et al., as illustrated for example in Fig. 2, from the solder side, a solder (PbSn which is Pb-rich), a solder reactive metal layer (Cu), a phased metal layer (CrCu), a barrier layer (Cr), a stress release layer (Cu), and an adhesive layer (Cr) are laminated. The phased layer (CrCu) represents a UBM layer. When the solder melts, the Sn of solder is reacted with the Cu reactive layer, or Sn of the solder is reacted with Cu of the CrCu phased metal layer. When the solder is reacted with the Cu layer, Sn of the solder reacts with Cu to produce a CuSn-alloy layer. As a result, in the case of the Cu layer being thick, a layer structure of solder, CuSn layer, Cu layer, and CrCu layer is obtained. On the other hand, when Sn of the solder reacts with Cu of the CrCu layer, a layer structure of solder, CuSn alloy, and CrCu layer is obtained. In the case of the Cu layer being thin, the entire Cu layer reacts and is dissolved into the solder. As a result, Cu of the CuSn alloy includes Cu of the CrCu layer because Cr does not react. Since Cr has low wettability, Cr does not react with any of Sn, Cu and Pb. Accordingly, the CrCu layer is not an alloy but a CrCu-mixed layer.

Although the CrCu phased metal layer of Chan et al can avoid diffusion, Chan et al still does not teach or suggest the feature of the present invention that the alloy layer of at least a main component of the alloy solder and a component different which is also different from a metal in the UBM layer is provided between the solder and the UBM layer, and thereby diffusion is prevented. That is, the Chan provides for a CuSn alloy layer where Sn is from the alloy solder, but where Cu is a component of the CrCu phased metal layer, or UBM layer, and does not satisfy the requirement of the present claims to include a second metal being different from a metal in the under-bump layer.

Marlin discloses an alternative structure as shown in Fig. 4 or Fig. 5 such that, from the solder side, a solder (Pb-free), a Cu layer, a Ni layer, and a TiW layer are laminated. However, Marlin's Fig. 6 shows only an example that one of Cu, Au and Ni is included in the solder on a TiW layer, and it is unclear how the layer 304 of Fig. 5 has been processed.

Marlin does not teach or suggest the feature of the present invention such that the alloy layer of at least a main component (for example, Sn) of the alloy solder and a second metal different from the metal that is the main component of the alloy soldier, said second metal also being different from a metal in the under-bump layer (for example, an under-bump layer including Ni) is provided between the solder and the UBM layer, and thereby diffusion reactions due to repeatedly applied heat processes are suppressed.

Marlin is directed to forming a solder on an optional support stud without wetting by forming the support stud of Cu on a non-wettable layer of TiW. Marlin discloses that "After

heating and reflowing, the solder bump will envelope the support stud but will maintain the proper shape for use in bonding because of the presence of non-wettable layer." (See col. 3, lines 8-12 and Fig. 6). It is also clear from Fig. 6 that the Cu support stud (308) is enveloped by the solder bump (310) without forming an intermetallic compound of the present invention.

Even if Marlin's Cu support stud were to melt to produce an alloy layer as in the case of the present invention, then the melted Cu would become shaped like a ball on the non-wettable (TiW) layer due to surface tension of the solder and therefore the Cu support stud would not be able to keep its shape for bonding to the solder on the TiW layer.

In Darveaux et al (USP 6,201,305), a solder bump is formed on wiring (Cu or Al) by selecting one of Cu, Au, Ni and the like as a pad. However, Darveaux et al is silent on bonding conditions after melting. Accordingly, as in the case of Marlin, it is considered that diffusion reactions proceed due to repeatedly applied heat processes.

As described above, none of the cited references teaches an alloy layer provided between a solder and a UBM layer, of at least a main component of the alloy solder and a second metal different from the metal that is the main component of the alloy soldier, said second metal also being different from a metal in the under-bump layer. When soldering, the above alloy layer is first formed between the solder and the UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

It is considered that diffusion proceeds by substitution of metal atoms and grain boundary motion. As for both Cu and Ni, a similar reaction occurs. However, when an intermetallic

compound has been formed for one, the other blocks the intermetallic compound to cut diffusion paths. Therefore, when the CuSn, for example, is initially formed at their interface, the Ni diffusion is suppressed.

In other words, according to the present invention, the solder and Cu for example, or the solder, Cu and Ni for example react to produce an alloy layer, and thereby diffusion reactions due to repeatedly applied heat processes can be suppressed.

For the foregoing reasons, Applicants submit that the combination of Marlin with Chan, and further in view of Darveaux, does not disclose, teach or suggest each and every requirement of Applicants' claims. Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a) in view of Marlin, Chan, and further in view of Darveaux.

**C.** Claims 13 and 17 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin and Chan et al as applied to claims 1, 5 and 9 above, and further in view of Andricacos et al (US Pat. 6,224,690) for the reasons given in the Office Action.

Claims 15 and 19 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin and Chan as applied to claims 3, 7 and 11 above, and further in view of Andricacos for the reasons given in the Office Action.

Claims 14 and 18 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 2, 6 and 10 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Claims 16 and 20 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 4, 8 and 12 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Applicants traverse the rejections.

Based on the amendment to Claims 1-4 and 158 and the remarks presented above in the obviousness rejections over Marlin in view of Chan, and further in view of Darveaux, Applicants submit that neither Darveaux or Andricacos or their combinations fail to overcome the previously cited deficiencies as reflected in dependent claims 13-20.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a).

*New Claims 159-162*

New Claims 159-162, dependent upon Claims 1-4, respectively, claim a semiconductor device wherein the alloy solder does not contain lead. Support can be found, for example, on page 1, Field of the Invention and on page 16, first full paragraph, describing lead-free solder bumps. No new matter is added. Entry of the new claims is respectfully requested.

Applicants point out that Marlin discloses solder bumps of lead-tin solder and other types of solder including lead-indium and tin-silver solder (see Marlin, col. 2, lines 15-18); and Chan et al. discloses that the solder of element 22 in Fig. 1 is PbSn (see Chan et al., col. 3, lines 46-54) and that the solder layer is preferably PbSn, AuSn, PbIn, AuIn, AuInSn or BiSn (col. 4, lines 11-

13). On the other hand, the present invention of Claims 169-172 require that no lead be contained in the soldier alloy.

Accordingly, Applicants respectfully request entry of the new claims and consideration of these claims for allowance.

***Conclusion***

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

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